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Study on the influence of groundwater seepage on the form of the layout of soil source heat pump

Li Bai *,Wenhao Che , Sai Wang

Jilin Jianzhu University,Xincheng Avenue NO.5088,Jingyue Development zone , Changchun ,130118,China

Abstract

Using the finite element analysis software FLUENT to simulate the heat flux changes and the average changes of underground soil temperature of soil source heat pump , at the same time simulating the heat flux changes and the average changes of underground soil temperature when there is groundwater seepage, providing some guidance for engineering construction.

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Keywords: ground source heat pump;groundwater seepage:arrangement;same intervals;different intervals;

1. Introduction

According to the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD) published 324 ground source heat pump project statistics by[1], at present in our country the soil source heat pump has the highest share in the heat pump system, the main reason is that the soil source heat pump with the characteristics of high efficiency and energy saving, without geographical restrictions and less polluting. Soil is a porous medium composed by the gas, liquid and solid, in practical engineering the heat exchanger buried depth is generally about 100m by[2],and soil is saturated in this depth, so the heat transfer of groundwater seepage to soil cannot be ignored. As the buried pipe area is limited by the practical engineering conditions, the study of borehole heat exchangers arrangement considering groundwater seepage has an important guiding significance for ground source heat pump design.

In this paper GAMBIT software was adopted to establish the model and dividing grid, the FLUENT software was

*Li Bai . Tel.: +86 0431 84566146; fax:+86 0431 84566146.
E-mail address: chinaheart1989@sina.com

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used for the numerical simulation of the model under the condition of the soil has groundwater seepage and without groundwater seepage ,and simulated the impact on soil heat transfer in the case of different arrangement of the well and different well intervals

2. The mathematical model of saturated porous media

1) The Momentum equation of the porous media has an additional source term, source term was composed of two parts: viscous loss terms and internal loss items, the equation of homogeneous and isotropic porous medium is by[3]:

$$S_i=\frac{\mu}{\alpha}\mathcal{V}_i+C_2\frac{1}{2}\rho|\mathcal{V}_j|\mathcal{V}_j \tag{1}$$

Among them, α is permeability; C_2 is internal resistance factor.

2) The energy equation in porous media

$$\frac{\partial}{\partial t}[\phi\rho_f h_f+(1-\phi)\,\rho_s h_s]+\frac{\partial}{\partial x_i}(\rho_f u_i h_f)=\frac{\partial}{\partial x_i}(k_{eff}\frac{\partial T}{\partial x_i})-\phi\frac{\partial}{\partial x_i}\sum_{j'} h_j\, j_{j'}+\phi\frac{Dp}{Dt}+\phi\tau_{ik}\frac{\partial u_i}{\partial x_k}+\phi S_f^h+(1-\phi)\,S_s^h \tag{2}$$

$$k_{eff}=\phi k_f+(1-\phi)\,k_s \tag{3}$$

Among them, φ is the porous nature of the porous medium; h_f is the enthalpy of the fluid; h_s is the enthalpy of the solid; S_f^h is the source term of fluid enthalpy;S_s^h is the source term of solid enthalpy; k_{eff} is the effective conductivity of the porous region; k_f is the fluid thermal conductivity; k_s is the solid thermal conductivity by[3].

3. The establishment of the simulation problems

In this paper, the number of in-line well group amount to 25 wells, According to China's national standards, the well interval of GSHP system are set to 3m, 4m, 4.572m (minimum well intervals of ASHARE manual recommended), 5m, 6m, Respectively corresponding to the total simulation area of 18m×18m、24m×24m、27.432m×27.432m、30m×30m、36m×36m. Other parameter settings were shown in the table below.

Table 1.Parameter setting

parameters	value	parameters	value
soil density	1975kg/m^3	the soil initial temperature	9℃
soil specific heat capacity	895J/ (kg·K)	soil porosity	0.3
soil thermal conductivity	2.2W/ (m·K)	inertia resistance coefficient	181481
groundwater velocity	2.2 ×10^{-6}m/s	viscous drag coefficient	3.267 ×109

4. Analysis of simulation result

According to the parameters, studying the soil temperature by simulation calculation. Fig.1 shows the distribution of soil temperature after three months operation when there is no groundwater seepage, Fig.2 shows the distribution of soil temperature after three months operation when there is groundwater seepage, and both the well interval is the same, the same as 5m.

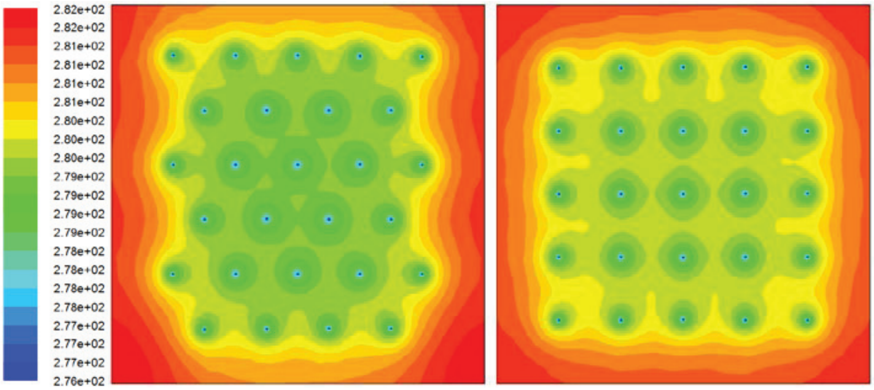

Fig. 1 The soil temperature distribution of the heat pump after three months operation when there is no groundwater seepage

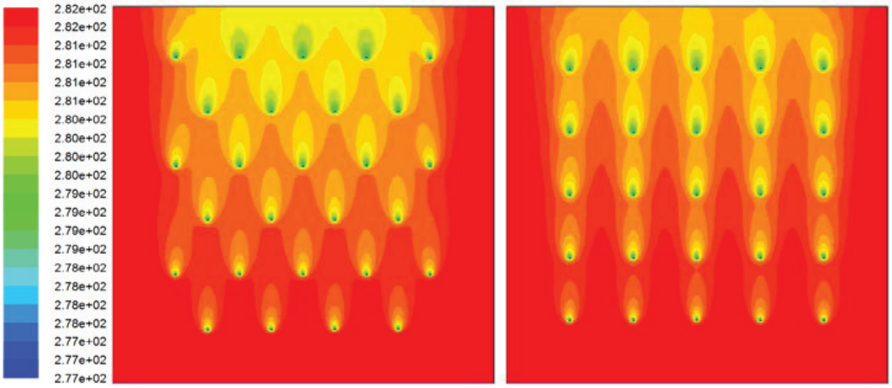

Fig.2.The soil temperature distribution of the heat pump after three months operation when there is groundwater seepage

The average soil temperature of staggered arrangement in Fig.1 is 7.98℃, in-line respectively is 8.02 ℃, the average soil temperature of staggered arrangement in Fig.2 is 8.37 ℃, in-line respectively is 8.44 ℃., What can be seen from Fig.1 and Fig.2 is that the distribution of soil temperature when there is groundwater seepage is basically centrosymmetric, the temperature field deformed under the action of groundwater seepage, weakened the soil cold accumulation caused by air conditioning system, cold effect radius of heat exchanger becomes small, the temperature of soil without groundwater seepage has some cold accumulation phenomenon, temperature is lower than the temperature with seepage of groundwater, the difference in temperature between them is about 0.4℃.

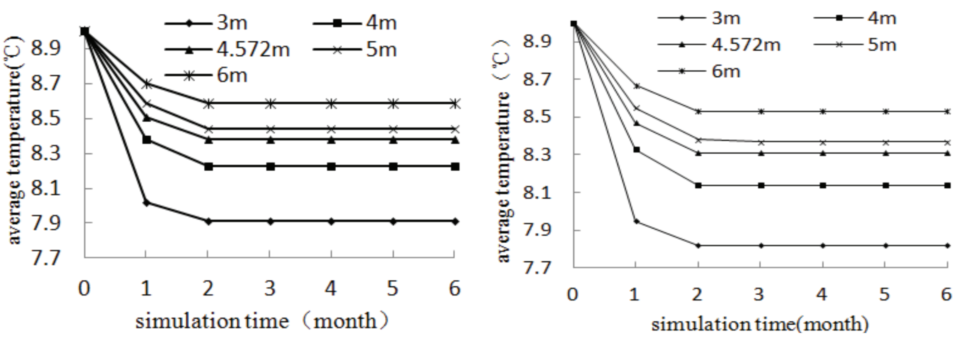

Fig.3 the average soil temperature with groundwater seepage of in-line arrangement

Fig.4 the average soil temperature with groundwater seepage of staggered arrangement

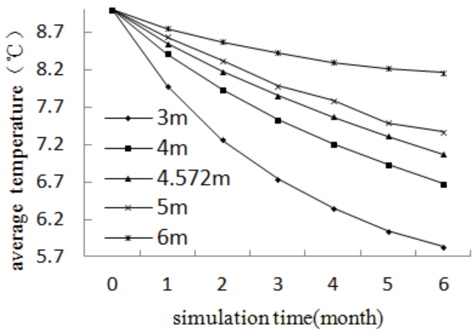

Fig. 5 the average soil temperature without groundwater seepage of in-line arrangement

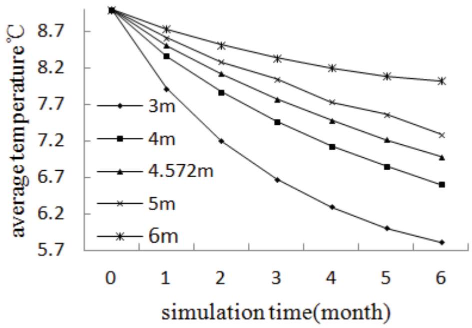

Fig. 6 the average soil temperature without groundwater seepage of staggered arrangement

What can be seen from Fig.3 and Fig.4 is that when there is groundwater seepage, take 5m interval for example, the soil temperature was in a steady state after 2 months of continuous operation and the temperature changes was small, the temperature drop of in-line arrangement is 0.63℃, staggered is 0.56℃ respectively; when there is no groundwater seepage, the soil temperature was gradually decreased, the temperature drop of in-line arrangement is 2.82℃, staggered is 2.87℃ respectively, the cooling rate is bigger, which is not conducive to long-term operation of GSHP system.

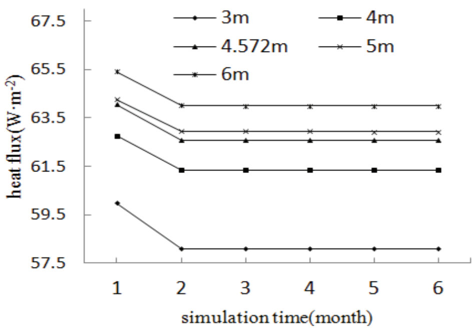

Fig.7 the heat flux with groundwater seepage of in-line arrangement

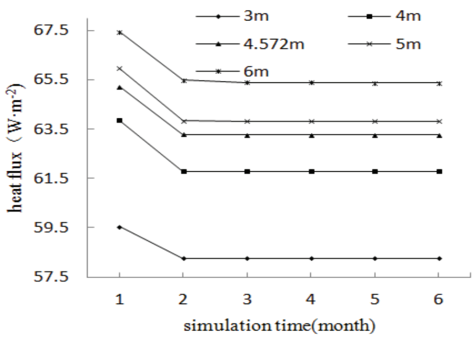

Fig.8 the heat flux with groundwater seepage of staggered arrangement

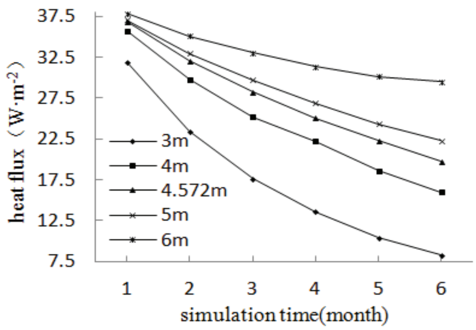

Fig. 9 The heat flux without groundwater seepage

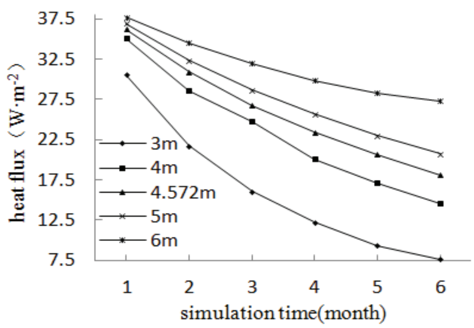

Fig.10 The heat flux without groundwater seepage

of in-line arrangement of staggered arrangement

What can be seen from Fig.7 and Fig.8 is that when there is groundwater seepage, take 5m interval for example, after two months of continuous operation, the sidewall heat flux changes are gradually stabilized, at this time, wall heat flux of staggered arrangement is 63.81W/m^2, in-line arrangement is 62.59 W/m^2 respectively, heat flux staggered is greater than in-line arrangement, which is contrary to the wall without groundwater seepage, this is because the staggered arrangement enhanced the heat transfer by the way of thermal disturbance when there is groundwater seepage. What can be seen from Fig.9 and Fig.10 is that, because there is no groundwater seepage, heat flux decreased gradually with system running time increased, at the end of heating season, staggered arrangement wall heat flux is 20.76W/m^2, in-line arrangement is 22.28 W/m^2 respectively, compared with in-line arrangement, staggered is not conducive to the operation of the system.

From the above we can see that, if in the design of GSHP system without considering the influence of groundwater seepage, it will cause the design of underground heat exchanger well number too much ,as well as cause resource capacity costs, therefore, engineers should consider the influence of groundwater seepage in the design of GSHP system.

4. Conclusion

To sum up, in the design of GSHP system, engineers should consider the effect of groundwater seepage on heat exchanger, avoiding the design of well hole is more than the number of actual demand, resulting in a waste of resources; at the same time, in order to achieve the best effect of heat transfer, engineers should adopt the most appropriate way of well arrangement(staggered, arranging, etc.) after comprehensive consideration.

REFERENCE

[1] Du Shi-min,Liu Ye-feng,Xiong Yue-zhong,et al. Research status and development trend of hybrid ground source heat pump systems[J].Energy Engineering,2014(4):59-65.
[2] Yang Gang-jie，Guo Min. Research on group arrangement method of ground heat exchanger under coupled thermal conduction and groundwater seepage conditions[J].Renewable Energy Resources,2014,32(8):1182-1187.
[3] Wang Jin-xiang,Li Su-fen,Shang Yan,Dong Ming,Wang Zheng..Underground Humid Soil Model Considering Conduction and Groundwater Advection and Numerical Simulation on Soil Temperature Field Around Underground Heat Exchanger, Acta Energiae Solaris Sinica,2008,29(7):837-841.